Measurement of Soot Oxidation in Post Flame Gases

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Introduction

In fires, the concentrations of soot and carbon monoxide are found to be strongly correlated [1] and a significant fraction of the CO emitted from fires is believed to originate from soot particle oxidation. There have been a number of studies of particle oxidation within flames [2,3,4,5]. and in shock tubes [6,7], but little work on post-flame oxidation [8]. We have recently initiated a study of the transformation of post-flame smoke with an emphasis on the chemical transformation of surface-adsorbed polynuclear aromatic hydrocarbons and the subsequent formation of gas phase molecular oxidation products. Some preliminary results from these studies are described below.

Experimental

Figure 1 shows the configuration of the apparatus used in these studies. The burner consists of a central fuel tube that is 1/4 inch diameter surrounded by a ~3/4 inch diameter air co-flow tube to stabilize the flame. This burner is fitted into a 1 inch diameter sleeve which allows for vertical movement of up to 3.5 inches. There is a six way cross above the burner region which allows for optical and/or probe sampling of either the flame or immediate post-flame gases. A 1 inch diameter, 25 inch long quartz tube is enclosed by a tube furnace which operates at 400 - 1500 degrees Celsius. Above this is another six way diagnostics cross.

We have used two fuels for the prêliminary studies. The first flame studied was an acetylene/air diffusion flame, desirable because of its low sooting height [9]. Extinction measurements were taken during heavily sooting conditions in the upper cross using a 1 mW HeNe laser operating at 632.8 nm while the tube furnace was adjusted to between ambient temperature and 700 °C. The beam was chopped at approximately 86 Hz and was monitored by photodiodes before and after the upper sampling region. Each signal was processed through an amplifier and a oscilloscope. The flow of soot through the sampling region was generally laminar but tended to drift during the course of the optical measurements.

In the second flame, a mixture of toluene in methane was used as the fuel. In the initial studies, the air flow was varied so that the global equivalence ratio in the burner varied between 0.5 and 1.2. The over-ventilated flame was non-smoking. However, as the overall stoichiometry became rich, the flame emitted smoke which could be detected via scattering and extinction of the HeNe laser beam.

Preliminary Results and Future Work

Figure 2 shows the results of the extinction measurements of the soot particles after the furnace region in the acetylene/air flame. The measurements show little reduction in smoke yield until the furnace temperature exceeds 500 °C. After this temperature, soot yield decreases rapidly with increasing temperature.

In addition to a more complete characterization of the light scattering and extinction measurements, we will perform a number of other diagnostic tests in this system. These will include

- particulate sampling and analysis of adsorbed Polycyclic Aromatic Hydrocarbons (PAH) using GC/MS
- particle morphology using scanning tunnelling microscopy (STM) and/or atomic force microscopy (AFM)
- tunable diode laser absorption spectroscopy (TDLAS) of CO and CO_2 which will provide quantitative information on soot oxidation rates.

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References

1. Koylu, and Faeth, G.M., "Soot Emission from Liquid Fueled Buoyant Turbulent Diffusion Flames," *Combustion and Flame* **87**, 61-76 (1991).
2. Puri, R., Santoro, R.J. and Smyth, K.C., "The Oxidation of Soot and Carbon Monoxide in Hydrocarbon Diffusion Flames," *Combustion and Flame* **97**, 125-144 (1994).
3. Skaggs, R.R. and Miller, J.H., "A Study of carbon Monoxide in a Series of Laminar Ethylene/Air Diffusion Flames Using Tunable Diode Laser Absorption Spectroscopy," *Twenty Fifth Symposium (International) on Combustion, The Combustion Institute, in press.*
4. Santoro, R.J., Yeh, T.T., Horvath, J.J. and Semerjian, H.G., "The Transport and Growth of Soot Particles in Laminar Diffusion Flames," *Combustion Sci and Tech.* **53**, 89-115 (1987).
5. Megardis, C.M. and Dobbins, R.A., "Comparison of Soot Growth and Oxidation in Smoking and Non-Smoking Ethylene Diffusion Flames," *Combustion Science and Tech.* **66**, 1-16 (1989).
6. Park, C. and Appleton, J.P., "Shock-Tube Measurements of Soot Oxidation Rates," *Combustion and Flame* **20**, 369-79 (1973).
7. Roth, P., Brandt, O. and Von Gersum, S., "High Temperature Oxidation of Suspended Soot Particles Verified by CO and CO_2 Measurements," *Twenty Third Symposium (International) on Combustion, The Combustion Institute,* 1485-1491 (1990).
8. Noirot, R., Gilot, P., Gadiou, R., and Prado, G., "Control of Soot Emission by Filtration and Post-Combustion. A Laboratory Study of the Regeneration of an Organic Particulate Trap Assisted by Hydrocarbon Injection," *Combustion Science and Tech.* **95**, 139-160 (1994).
9. Schug, K.P., Manheimer-Timnat, Yaccarino, P. and Glassman, I., "Sooting Behavior of Gaseous Hydrocarbon Diffusion Flames and the Influence of Additives," *Combustion Sci and Tech.*, **22**, 235-50 (1980).

FIGURE 1

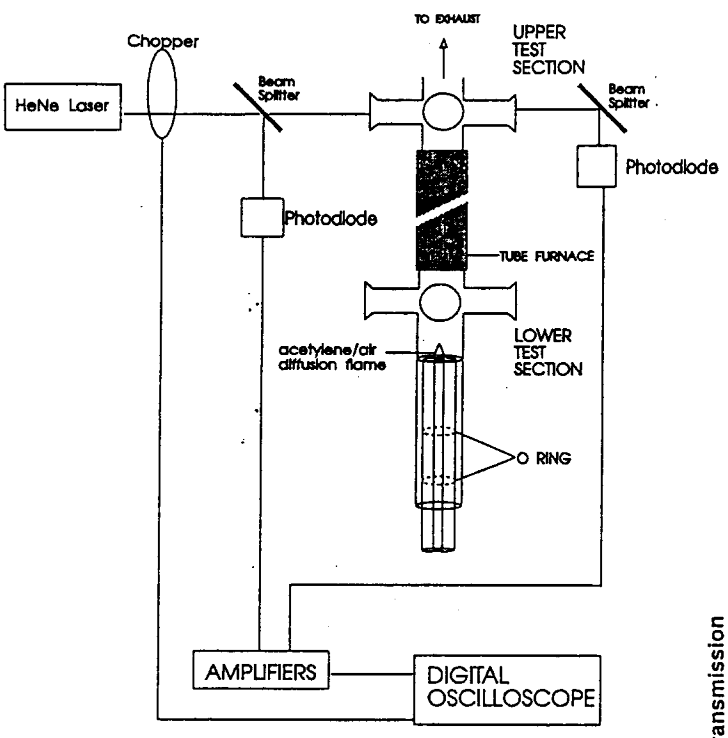

FIGURE 2